

Our city planning commission, in co-operation with the Chicago Regional Planning Association, is attempting to assume some of the responsibility for planning future traffic routes through Gary and the Calumet Region; and while not wishing or intending to usurp any of the responsibility placed on the State Highway Commission, we do feel that the local group has a definite responsibility to the city and can best serve that responsibility by intelligently sharing the burden with the state authorities.

FUNDAMENTALS OF ROAD AND SUBGRADE STABILIZATION

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Doubtless many of you have read the title assigned to me and have wondered just exactly what I might select to talk about. Engineers have built gravel roads for many years. Sometimes we call them traffic-bound roads. A few years ago the word "stabilization" began to be heard frequently. Most of us did not know exactly what was meant when we talked of a stabilized road—and we still don't know. In fact, this question came up in the materials group at the last meeting of the American Association of State Highway Officials and a committee was appointed to write a definition of stabilization. Inasmuch as we do not at present have a definition of my subject, it seems to me that my field is unlimited.

Because gravel and crushed stone are available over a large part of Indiana, many of us have become accustomed to think of a stabilized road as one consisting of gravel or crushed stone that has been tied down by clay and chemical. We think of a traffic-bound road as one on which we have placed a granular material with the hope that it compacts under traffic in somewhat less than a year, whereas we think of a stabilized road as one that is thoroughly compacted and stabilized as a part of the construction. I do not think that this idea of a stabilized road is one that will conform with the definition that will be suggested by the committee appointed to define stabilization. But suppose that, for the purpose of discussion, we assume that we are planning to build a road of this type about six inches thick. Let us suppose also that at least a part of the subgrade on which we plan to place the new surface is heavy clay. We all know that this relatively thin course of stabilized aggregate on a wet clay subgrade will not carry heavy traffic satisfactorily. As was pointed out by Mr. Macadam, for whom the macadam-type road was named, over one hundred years ago, the subgrade must carry the load transferred to it by the base course.

If the subgrade is deformed or moves under this load, the surface also moves. Obviously, one of the chief worries of a road-builder should be the question of the stability of the subgrade, and the lower the type of road we plan to build, the more important a good subgrade becomes.

Indiana has many miles of flexible-base roads twelve inches or more thick that have carried traffic satisfactorily for years. Although there may have been some, I do not know of a single failure that has occurred on pavements twelve inches or more thick that can be attributed to base failure. These surfaces were placed on all types of subgrades with very little, if anything, being done to correct bad places. And yet they do not fail. But when we consider surfaces eight inches thick, we have a different story. If I were to enumerate all the failures that have occurred on eight-inch flexible-base roads in Indiana, it might be embarrassing. On a sand subgrade, however, eight inches is more than we need in many cases. The point I am trying to make is that, the thinner the surface, the more important it becomes that the subgrade be good. I do not agree with those who argue against subgrade treatment because we are building a low-cost road. I believe that something ought to, and can, be done to help stabilize subgrades, but that *something* should result in a better road at a lower ultimate cost.

SUBDRAINAGE

There are times when tile drains are worth the cost involved. Where we have a reasonably good soil for a subgrade that is underlaid by a porous, water-bearing sand, it often happens that tile placed at the proper elevation in the ditch line will intercept the water before it reaches the road. But this isn't always true. In the summer of 1938, Indiana State Road 34 west of Waynetown was under construction. I was driving over the completed grade and came to a place about 400 feet long that was barricaded to keep all traffic off it. I got out and looked to see what might be the trouble. The soil here was quite wet, whereas the rest of the grade was fairly dry. I picked up a handful. It felt floury and slippery without being sticky. It didn't feel as though it had any sand in it; but when I took a bite of it, it tasted plenty gritty. It was what I would diagnose as a perfect case of unstable silt. Soils of this type have the faculty of drawing enough water by capillary attraction from their surroundings to make them quite unstable. They heave badly when frozen. When I got a little farther down the grade and met the project engineer, he informed me that the soils department of the State Highway Commission had investigated this section and found that a layer of sand existed about two or three feet underneath the surface, *but* that there wasn't any free water in the sand. If there wasn't any free water, there

wasn't any use in placing a tile drain. I believe the soils department recommended that the silt be removed and replaced by more suitable material, which, in my opinion, was the correct thing to do. I wonder what the recommendation might have been if free water *had* been found in the sand. It is possible that subgrade tile might have been installed, and it is entirely probable that it would have had no effect in stabilizing the overlying silt.

In the report of the Bates Test Road in Illinois, published in January, 1924, two cases are cited where longitudinal tile drains were placed under each edge of a pavement. I quote from this report: "Moisture samples were taken from the underlying soil at various points throughout the tiled section and likewise from the adjacent undrained sections. During a period of three years, no measurable difference in the moisture content of the subgrade at these points was observed."

It should be understood that the soil in this locality is a heavy black clay. Farmers drain it with tile to such an extent that free water is removed, but the tile removes only the free water. Plenty of water is left in the soil to help produce some of the world's biggest corn crops, and this is enough water to make the soil unstable as a subgrade. Indiana has some soil of this type, too, besides the silty soil mentioned previously.

ADDITION OF GRANULAR MATERIAL

Well, suppose we can't get enough water out of our subgrade by tiling to justify the cost. What shall we do? One solution is to place a layer of granular material on the grade. It is generally considered good practice to place this material from shoulder to shoulder in order to allow the water to get out of it. The portion of the granular material that will be under the base course should be stabilized to the extent that it is firm and will allow construction equipment to pass over it without difficulty. A little top soil sprinkled over the top and disked in and rolled is satisfactory. It need not be an expensive task to get the necessary stability in sub-base material. Michigan pays for stabilizing sub-base by the station, and the bid prices average about \$5.00 a station.

In Indiana, the difficulty has often been that subgrade stabilization was an afterthought. If we wait until the grading is done and the contractor's equipment has left the location before we consider correcting the subgrade, the cost is sometimes found to be prohibitive. The time to think about subgrade correction is at the time the plans are being made. If we show on the plans that a layer of granular material is to be placed between certain stations and adjust the grade line accordingly, the cost will generally be reasonable.

A second objection to placing a layer of granular borrow on the subgrade in Indiana is that suitable materials are

often not available within a reasonable distance. Sometimes that objection is valid, but many times it is not. On the Waynetown project that had the bad silty subgrade mentioned previously, a cut was made about a half mile down the road in a sandy gravel that would have made excellent sub-base. Had this been spotted on the plans, it could have been hauled a half mile down the road and paid for as excavation plus overhaul. The total cost would probably have been less than fifty cents a cubic yard, whereas the bid price for such material was \$1.00.

As another example of overlooked opportunities I should like to call your attention to the huge stockpiles of stone screenings that most stone quarries are worrying about how to get rid of. If the stone quarries are willing to co-operate with the highway authorities by selling this waste material at a reasonable price, I see no reason why we couldn't use a lot of it. Stone screenings wet down and rolled in place make an excellent sub-base. Personally, I would prefer a twelve-inch layer of stone screenings to six inches of stabilized coarse aggregate, and I imagine that in many cases the twelve inches of stone screenings would cost less than six inches of coarser material. Granular material for sub-base may be anything that is available. It may be dune sand, strippings from a gravel pit, local bank-run material—or in some cases cinders or shale from the waste pile at coal mines. If, at the time plans are prepared, the highway authority in charge determines where sub-base material is needed and also where it can be obtained, the cost will many times be quite low. It would probably be desirable for the highway authority to get an option on the granular material it expects to use and then tell the contractors not only where they can get it, but also how much it will cost. The cost would be quite different from that obtained on one project last summer where we specified 75 cubic yards of granular material and got a price of \$2.75 a cubic yard.

GOOD AND BAD SOILS

The question of what soil makes a good subgrade and what one doesn't is one that has many of us guessing. I am afraid that there is no satisfactory substitute for a detailed soil analysis and an interpretation of the results by a competent soils engineer. Often we are not able to get this information in time to do much good. I am going to try to give you some sort of idea of what to expect of different soils. We all know that sand is good subgrade material and that silt and clay are not. The soils man's definition of sand is material passing the No. 10 sieve and retained on the No. 270 sieve. Anything passing the 270 sieve is silt and clay. Material retained on the 270 sieve is sand and is good subgrade material, whereas too much silt and clay in soils cause trouble. The difference be-

tween a 270 sieve and the standard 200-mesh sieve is not great. For the purpose we have in mind, the error will not be serious if we use the 200 mesh instead of the 270.

Most all of you can get hold of a 200-mesh sieve. If you have a questionable soil, wash it through a 200-mesh sieve and see how much is retained. Most Indiana soils that have as much as 60 per cent retained on the 200-mesh sieve make satisfactory subgrades. If less than 60 per cent is retained on the 200-mesh sieve, the proportion of silt and clay in the soil may be large enough to make it unstable when wet. I don't mean that this is a hard-and-fast rule. It certainly has exceptions. Soils having this amount of sand sometimes may be unstable in cuts because of lack of drainage or because of the nature of the surrounding soil. But the fact remains that the greater the proportion of sand we have, the better the soil as a subgrade, and that bad soils always contain a considerable percentage of silt and clay.

NEED OF COMPACTION

There is one more point regarding stabilization of the subgrade that appeals to me as being worth while. It is well known that the harder and more compact a soil is, the more stable it is. The state highway engineers recognize this in several ways—one is that they require that shoulders along new construction be rolled and well compacted in order that they will hold their shape better. Mr. Proctor, for whom certain compaction tests are named, states that the amount of water a soil is able to absorb is limited by the void or pore space in the soil. Therefore, the more compact the soil, the less water it is able to absorb and the more stable it remains. With this in mind it seems to me that it would be well worth while to make sure that the subgrade on which a surface is to be placed is thoroughly compacted. This applies to grades in cuts as well as on fills. It applies especially to subgrades on which flexible bases are to be placed.

So far I have been trying to tell you my ideas of the fundamentals of subgrade stabilization. My subject includes also the fundamentals of road stabilization. Those of you who attended the Road School last year had the opportunity of hearing a series of talks by prominent engineers on the several types of stabilized bases and surfaces. These contained much valuable information, and I should like to suggest that, if any of you are seriously interested in the construction of these types, you review the papers given here last year. It is not my intention to repeat any more of the information presented last year than is necessary. Three different types of stabilized roads were discussed in three different papers. These were stabilization with chemicals, with portland cement, and with bituminous materials.

SOIL-AGGREGATE BASES

First let us consider stabilized bases constructed with a graded gravel to which are added a little clay and some chemical, either calcium or sodium chloride. Probably the three most important things to remember in this type of construction are:

1. **Gradation.** The gradation of the gravel must be such that the resulting mixture has a low void content. This means that it is essential that the proper proportions of gravel, sand, silt, and clay must all be included in the mixture.
2. **Binder.** The proper kind and amount of soil binder must be used. The exact amount used depends on the quality of the particular soil selected. In general, the soil should be of the silty type rather than a heavy sticky clay. Heavy sticky clays are very difficult to mix with the gravel. When wet, they soak up so much water that they swell and make the gravel soft and muddy. Lighter, siltier topsoils when used in the proper amount do not swell. If no swelling of the soil binder occurs, the gravel remains firm even with an excess of water present.
3. **Compaction.** No base course is ready for a surface until it is thoroughly compacted. If it is not thoroughly compacted it will move and the surface course will crack, allowing water to enter and failure to result. In addition, thorough compaction increases the load that the material is capable of carrying.

Compaction is secured by adding water and calcium chloride and by rolling. The water helps the particles slide over each other and into the holes so that it is easier to get a dense mixture. The action of the calcium chloride is not thoroughly understood. However, information contained in the November, 1939, issue of *Public Roads* shows that in a test track the material containing calcium chloride compacted in about one-third the time required for the same mixture without the calcium. Mixes containing sodium chloride, or common salt, did not compact any more quickly than when no chemical was used. Both calcium and sodium chloride helped keep down dust and prevented ravelling in dry weather. Neither proved to be of any value after a surface was placed on the base course. If sufficient care is exercised to get thorough compaction and if ravelling is prevented by watering during dry weather, bases can be constructed without chemicals that are entirely satisfactory. If it is planned to place a surface course the same year the base course is placed, calcium chloride would seem to be a good investment because of the time saved in obtaining compaction.

We have been discussing stabilized gravel. Just as satisfactory bases can be built with crusher-run stone or slag, provided the same precautions are observed regarding gradation and compaction. For base courses there seems to be nothing gained by adding clay to crusher-run stone or slag. For surface courses a little clay is desirable to help prevent ravelling. If a road is to be used as a surface without any further treatment, it is essential that the surface crown be ample. A five-inch crown for stabilized surfaces is usually recommended, in order to make sure that water does not stand in depressions on the surface.

The average cost of several state projects in Indiana of plant-mixed, stabilized gravel or crushed stone was around \$2.00 a ton, or about \$7,000 per mile of road 20 feet wide and six inches thick. Of course, the cost varies considerably, depending on the availability of material. Even traffic-bound roads cost around \$6,000 a mile when built under state specifications. Although I have no figures, I understand that several counties have built satisfactory traffic-bound roads at costs lower than this. The reason that the counties have lower costs is probably that local materials were used without such strict specification limits as the state has. This does not necessarily mean that the county roads are not just as good.

PORTLAND CEMENT-SOIL ROADS

Roads have been constructed in several states by mixing portland cement with the soil in place on the road. These roads are most satisfactory if the soil is of a granular type. You may remember that I suggested that a soil containing at least sixty per cent retained on the 200-mesh sieve is likely to make a good subgrade. A large amount of data on the behavior of various soils mixed with cement has been accumulated. These soils are classified in three groups according to the quality of the resulting road surface when the soil is mixed with cement. These three classes might be called excellent, fair, and poor. All the soils investigated that showed excellent results when mixed with cement had at least 60 per cent retained on the 200-mesh sieve. For soils of this type, from 8 to 10 per cent of cement is generally satisfactory. Many soils having less than 60 per cent retained on the 200-mesh may be satisfactorily stabilized with cement, but the amount required may exceed 10 per cent.

It is not possible to determine by visual inspection the correct amount of cement required to be mixed with a soil. Laboratory tests are required. In general, however, granular soils show very good results, whereas it sometimes happens that so much cement is required to stabilize heavy clay soils that it is not economical. These soil cement roads are built by mixing cement, water, and soil on the road. Mixing equipment includes harrows, gang plows, and discs. The mixture

must be thoroughly compacted. Sheepsfoot rollers and flat-wheeled tandem rollers are usually used to obtain compaction. The average cost of a surface six inches deep and approximately 20 feet wide as obtained in several states is \$5,000 per mile. The most common amount of cement used on these projects was 10 per cent by volume.

Indiana received bids on at least one project of this type, however, and failed to get any bids under the engineer's estimate, which I believe was something like \$7,500 per mile. The reason for the high bids is not entirely clear, but the fact that local contractors had never built this type of road and probably did not have enough equipment of the type required was a big factor in the high bids received. Whenever a new type of construction is introduced, it is natural that the bids on the first few projects should be considerably higher than the bids received after the contractors have found out to their own satisfaction just what the costs really are.

BITUMINOUS STABILIZATION

Stabilization of the existing subgrade to make a base has been accomplished successfully by several states using bituminous materials. Here again, however, a granular material is much better than clay. Mr. Beckham of South Carolina has a very good article in the *Proceedings of the Eleventh National Asphalt Conference* dealing with stabilization with bituminous materials. He concludes that "soils containing as much as 45 per cent silt and clay can be satisfactorily stabilized with rapid curing cutback asphalt." The 45 per cent he mentions is not very far from the 40 per cent silt and clay that I mentioned as being somewhere near the maximum allowable to produce a satisfactory subgrade. Mr. Beckham thinks that a good way to construct a base course of soil and asphalt is by means of a travelling mixing plant—one that picks the material up out of windrows, mixes it, and deposits it back on the subgrade. In order to facilitate the mixing of asphalt and soil, water is added. A certain amount of water is also needed during compaction in order that a high degree of compaction may be obtained. Some data on costs are given. Converting the surfaces to a width of 20 feet and a depth of six inches, it cost South Carolina about \$6,300 a mile when the travelling mixer was used, and \$4,200 for a road-mixed project.

In 1937 Kentucky constructed a section about twenty miles long, using bituminous material to stabilize the surface in place. The existing surface consisted of about $1\frac{1}{2}$ inches of road metal on a rather silty subgrade. The grade as a whole had given continuous trouble for a number of years. Some of the road was stabilized with asphalt using a sub-oiler, and a travelling plant mixer was used on the rest. A sub-oiler, as most of you know, is a machine that shoots oil into the road

below the surface through scarifier teeth. Emulsions and medium-curing and slow-curing asphalts were used. The travelling plant-mix was not entirely satisfactory because of conditions existing on this project. It is necessary to have the windrow of material quite wet in order to get it through the travelling pug-mill mixer. The project was built late in the fall, and the water did not evaporate from the mixture. In soil-bituminous stabilization, water may be necessary to facilitate mixing, but the resulting mixture is no good until the water has been reduced to the optimum or below. This is a point worth remembering, because it has been responsible for poor results in a number of states. The costs varied from \$4,300 per mile for the sub-oiled section and slow-curing oil to \$8,900 per mile for the section mixed with a travelling mixer and asphalt emulsion. It seems probable that costs lower than this might be obtained on future projects after the contractors have become more familiar with the process. Recent reports from Kentucky indicate that this type of construction has not been very satisfactory. The cause of the poor performance has not been determined.

All of us would like to know how to build a good low-cost road. That seems to be one of the most difficult problems a highway engineer has to solve. It has often been said that the lower the type of road desired, the higher the grade of engineering required. No doubt this is true. I am sorry that I am not a good enough engineer to tell you definitely how to build a good road cheaply. I hope, however, that some of the things I have suggested will be found useful in constructing a more stable road at a reasonable cost.

ROAD-MIX VS. PLANT-MIX IN BITUMINOUS ROAD CONSTRUCTION

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It must be clearly understood at the beginning of this discussion that it is not my purpose to disparage road-mix bituminous construction and promote plant-mix construction, but to tell you why the Michigan State Highway Department has adopted plant-mix methods for its bituminous road program. From this discussion you may obtain some thoughts that will fit into your own situation.

There are many types and methods of bituminous-surface construction for highways in use throughout this country today. Certain factors or conditions, such as climate, character of traffic, available aggregates, first cost, and maintenance expense, lead different states and localities to select one or more types and methods of bituminous construction. The